

Study of Heavy Mesons Rare Decays and B_c^+ Mass and Lifetime Measurements at DØ

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Abstract

This summary reports some of the DØ experiment recent heavy flavour results. It is focused on two distinct topics. The first one is devoted to bottom and charm Flavour Changing Neutral Current rare decays and the second one concerns B_c^+ properties measurements.

Key words: Heavy Flavor, Rare Decays, Flavor Changing Neutral Current, Lifetime, Mass, DØ.

PACS: 12.38.Qk, 13.20.He, 13.20.Fc, 14.40.Nd, 13.25.Hw

1. Experimental environment

The Tevatron proton-antiproton collider produces large amounts of the heaviest bottom hadrons, even those which are not accessible at the $\Upsilon(4S)$ resonance. However the benefit of the high total $b\bar{b}$ and $c\bar{c}$ production cross-sections and of the high luminosity delivered by the Tevatron is reduced by the less clear hadron collider environment. Interesting processes have to be extracted from high track multiplicity events. Under these conditions, DØ's most important features are its good muon identification and its wide acceptance, allowing highly selective triggers mainly based on di-muon triggers.

The following results are based on data samples of integrated luminosity ranging from 1.3 to 2.0 fb⁻¹. During the summer 2006, the vertex detector has been upgraded by inserting an additional layer of silicon strip detectors close to the beam pipe. Data taken before are referred to as Run IIa data and correspond to 1.3 fb⁻¹, those taken afterwards are called Run IIb, which is currently ongoing.

2. Bottom and charm mesons rare decays.

Processes involving Flavour Changing Neutral Currents (FCNC) in the bottom sector provide sensitive signatures to search for new physics since they have small branching

ratios in the Standard Model, while enhancements by several orders of magnitude occur in many models beyond the Standard Model. Other theoretical scenarios predict deviations from the Standard Model only in the up quark sector so that we are also interested in charm meson FCNC decays. However in charm decays the FCNC contribution may be screened by long distance interactions with no sensitivity to new physics. For several FCNC rare decays the experimental sensitivity is now reaching the Standard Model expected rates. This is not the case for the two results reviewed here on the $B_s^0 \rightarrow \mu^- \mu^+$ and the $D^+ \rightarrow \mu^+ \mu^- \pi^+$ branching ratios, which are expected to be as low as 10^{-9} [1], thus still leaving an opportunity to search for new physics.

The selection of the rare $B_s^0 \rightarrow \mu^- \mu^+$ decay channel is based on a set of sequential cuts followed by the use of a likelihood discriminant to further reduce the background. The content of the $\mu^- \mu^+$ invariant mass signal region was not unveiled until all selection criteria were optimized. The expected background in the signal region has been estimated by interpolating the sideband population and amounts to 0.8 ± 0.2 and 1.5 ± 0.3 for Run IIa and Run IIb data respectively, while the observed events amount to 1 and 2 respectively. In the absence of an observation, a limit is put on the $B_s^0 \rightarrow \mu^- \mu^+$ branching ratio, normalized to the number of reconstructed $B^+ \rightarrow J/\Psi K^+$ with $J/\Psi \rightarrow \mu^- \mu^+$. This decay channel is reconstructed with the same kind of criteria and allows some systematics cancellation. To simplify the calculation of the branching ratio the conservative assumption that there is no contribution from $B_d^0 \rightarrow \mu^- \mu^+$ decays in the search mass windows is made. A Bayesian limit is derived: $\mathcal{B.R.} < 7.5 \times 10^{-8}$ at 90 % C.L [2].

For the search for the FCNC contribution to the rare $D^+ \rightarrow \mu^+ \mu^- \pi^+$ decay, a first step consists in searching for D^+ and D_s^+ candidates with an intermediate $\phi \rightarrow \mu^+ \mu^-$ resonance state. Clear indication of D^+ and D_s^+ decaying to $\phi \pi^+$ is observed with a significance greater than 4σ for the D^+ state. The yield ratio of D^+ with respect to D_s^+ is related to the ratio of the corresponding branching ratios, reconstruction efficiencies and production fractions. Using the known branching ratio for the D^+ decay, the branching ratio of $D^+ \rightarrow \phi \pi^+ \rightarrow \mu^+ \mu^- \pi^+$ is measured to be 1.8 ± 0.5 (stat) ± 0.8 (syst) $\times 10^{-6}$ [3], in good agreement with the expected value given by the simple factorization of the two sequential decays. The continuum decay $D^+ \rightarrow \mu^+ \mu^- \pi^+$ mediated by FCNC interactions is then searched in a second step of the analysis, by looking for an excess of D^+ candidates for which the di-muon invariant mass is inconsistent with the ϕ mass. For these selected events, the signal region contains 19 events, to be compared with 25 ± 8 expected combinatorial background events obtained by interpolating the sideband population. This yield is normalized to the $D^+ \rightarrow \phi \pi^+ \rightarrow \mu^+ \mu^- \pi^+$ yield and a Bayesian limit is derived: $\mathcal{B.R.} < 3.9 \times 10^{-6}$ at 90 % C.L. [3], which is the most stringent limit at present.

3. B_c^+ properties

The doubly heavy B_c^+ meson has already been observed during the Tevatron Run I [4]. However its properties had to wait for the Run II to be measured. Its lifetime is expected to be much shorter than that of the other weakly decaying b hadrons because also the charm quark can decay. Current theories span from 0.47 ps to 0.59 ps [5] and

experimental results with small uncertainties will provide useful inputs for the theoretical calculations.

The B_c^+ lifetime is measured in the $J/\Psi\mu\nu \rightarrow 3\mu$ channel. The reconstructed transverse decay length is corrected for the missing neutrino momentum and used as a lifetime estimator. The main challenge of this analysis consists in obtaining the sample composition, which is overwhelmingly background dominated. The sample composition and the B_c^+ lifetime are simultaneously measured by comparing the observed lifetime estimator and the 3μ invariant mass distributions using a maximum likelihood method. The measured lifetime is $\tau(B_c^+) = 0.448^{+0.038}_{-0.036}$ (stat) ± 0.032 (syst) ps [6].

The hadronic mode $B_c^+ \rightarrow J/\Psi\pi^+ \rightarrow \mu\mu\pi^+$ is more suitable for mass measurement given its fully exclusive reconstruction. The selection begins with the J/Ψ reconstruction to which a third track is added, forming a common vertex. When this third track is assumed to be a K^+ , a clean high statistics B^+ signal sample is obtained. This sample with similar topology than the searched B_c^+ is used as a reference in an initial step of selection criteria optimization. Then, due to the B_c^+ higher invariant mass and its shorter lifetime, its specific selection criteria are further optimized using simulated events. A clear excess is seen in the $J/\Psi\pi^+$ invariant mass distribution after this optimized selection, corresponding to a significance higher than 5σ . The result of an unbinned maximum likelihood fit to this signal gives a measured mass of $M(B_c^+) = 6300 \pm 14$ (stat) ± 5 (syst) MeV/c² [7] for a yield of 54 fully reconstructed B_c^+ . This measured mass is consistent with the latest and most precise theoretical prediction [8].

4. Conclusion

In heavy flavour physics at the Tevatron, the analysis sensitivities are expected to keep improving as larger datasets are included. The Tevatron has already delivered more than 5 fb^{-1} to the DØ experiment and only 1.3 to 2 fb^{-1} were analysed in the results reported in this proceeding. Concerning the heavy meson rare FCNC decays we have seen that DØ's sensitivity is reaching the 10^{-8} level. These results allow to further constrain the new physics models and they complement direct searches for new phenomena. Concerning the B_c^+ meson, after the confirmation of its observation, we are now entering a new phase of properties measurements.

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